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Canada Mortgage
and Housing Corporation

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PART V REPORT

NATURE, EXTENT, AND IMPACT OF RESIDENTIAL PARKING STRUCTURE DETERIORATION

Prepared for
The Technical Research Division
Policy Development & Research Sector
of
Canada Mortgage and Housing Corporation
by

TROW LTD.

November, 1981.

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Canada Mortgage and Housing Corporation
Société canadienne d'hypothèques et de logement

Canadian Housing Information Centre
Centre canadien de documentation sur l'habitation

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EXECUTIVE SUMMARY

The deterioration of parking structures in Ontario and some other provinces is reaching epidemic proportions.

Almost all parking structures built to current design and construction standards are deteriorating.

Costs of repairs can, after only a few years of service, equal or exceed the initial construction cost. In any event, most repairs are costly and are palliative rather than curative.

These are creating a number of increasingly serious problems.

1. Major lending organizations face an increased risk because of value loss as a result of deterioration of these structures.

2. Public and private owners face a similar loss of value and increasingly onerous maintenance costs.

3. Where the owner is a condominium, such costs can reach unmanageable levels for the private individuals involved.

4. There is increasing danger of structural collapse with time.

Missing, to date, is any data on the total potential economic impact of this problem on the housing market.

It was the purpose of this research programme to begin the process of assessing this economic impact.

The residential buildings in the sample area exhibit the typical signs of deterioration common to all parking structures in areas where de-icing salts are used in winter. At the moment, the 84 structures in the sample survey require approximately $10,000,000. worth of repairs and $750,000. worth of Engineering services to restore them to acceptable condition and to protect them from further significant deterioration assuming normal maintenance is continued.

The financial analysis further confirms that the recommended system of repairs and waterproofing carried out to high standards is significantly cheaper in the long run than the use of less desireable but initially cheaper repair methods.

It is recommended that a larger sample, covering a number of other geographic areas, be surveyed to determine to what extent the initial survey area was typical of the rest of Canada. This survey should also include sufficient technical input to determine why the structures greater than 10 years old appear to be more durable, and why, within the same age ranges, there is a wide difference in the durability performances of similar structures.

It is further recommended that existing programmes such as RRAP be examined to see if some relief can be afforded to the owners of residential property - particularly condominium owners.

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INTRODUCTION

The deterioration of parking structures in Ontario and some other provinces is reaching epidemic proportions.

The principal cause of damage is the use of de-icing salts[1].

Almost all parking structures built to current design and construction standards are deteriorating.

Costs of repairs can, after only a few years of service, equal or exceed the initial construction cost. In any event, most repairs are costly and are palliative rather than curative.

These are creating a number of increasingly serious problems.

1. Major lending organizations face an increased risk because of value loss as a result of deterioration of these structures.

2. Public and private owners face a similar loss of value and increasingly onerous maintenance costs.

3. Where the owner is a condominium, such costs can reach unmanageable levels for the private individuals involved.

4. There is increasing danger of structural collapse with time.

To date, no concerted efforts have been made to solve these problems.

Some technical activity has recently begun.

At the 1979 Fall Convention of the American Concrete Institute in Washington, the formation of a committee on Parking Structures was authorized. This committee has been formed and is drafting a code of practice.

In November, 1979, the Ontario Chapter of the American Concrete Institute formed a committee on parking structures and has recently produced a guideline document on the investigation, repair, and design of parking structures. Three Ontario Provincial Ministries are represented on this committee - Transportation and Communications; Housing; and Consumer and Corporate Affairs.

At the Annual Meeting of the Municipal and Parking Congress in Los Angeles in July, 1980, it was resolved that one of the first priorities is an inventory of parking structures. This and other matters relating to this problem were considered at the Transportation Review Board meeting in Washington in January, 1981.

Missing, to date, is any data on the total potential economic impact of this problem on the housing market.

It is the purpose of this research program to begin the process of assessing this economic impact.

Once this is done the public and private institutions involved in the finance and ownership of housing will have the necessary data on which to base their decision making.

OBJECTIVES

To qualify and quantify the problems associated with the in-service performance of parking garages serving residential buildings. Document the nature and known extent of the problem so that even a non-technical reader can be made aware of the overall problem. Ensure that the main thrust of the study was to assess the economic impact and implications of deterioration.

SCOPE

Because of the size of the housing market, this study was limited to one geographic area; Ottawa. 84 parking structures were involved.

METHODS EMPLOYED

Collection of Data

The collection of data for this assignment required the completion of a number of intermediary steps. These steps are briefly summarized below.*

Compile List of Ottawa Apartments

Based on our library files, information obtained through the Ottawa Real Estate Board and site inspections, an initial list of apartments with parking facilities was assembled.

Initial Contact - Introductory Letter

Given the list of apartment addresses, tax assessment data was consulted to identify the building owners. An introductory letter briefly outlining the study objectives was then sent to the owners soliciting their participation in the study. A copy of this letter is attached as Appendix "A".

The owners of 165 apartment buildings with parking facilities were contacted. From these, data for 84 residential parking facilities was collected, a response rate of 51%. In accordance with our prior agreement to ensure anonymity for the owners, the apartments have been given a number for which we retain the key on our files.

* Note: The methodology used to assemble the data was deemed to be statistically sound by Statistics Canada.

Interviews

A follow-up telephone call was made and an appointment was arranged with the appropriate individual (usually the Property Manager). The interview questionnaire was administered and approval for parking facility inspection and the name of a contact person at the building was received. A copy of the interview questionnaire is attached as Appendix "B".

Parking Facility Inspection

The parking facilities were inspected, the degree of deterioration was noted and then recorded on the questionnaire. The field researcher collecting this data was given a pre-study seminar on the identification of the major symptoms of structural deterioration. Subsequently, to ensure proper analysis, it was found necessary to re-survey all structures by an Engineer with extensive experience of parking structure deterioration.

Tabulation of Survey Results

As a final step, the questionnaires were coded and tabulated as Tables 1, 2 and 3:

Table 1	General Information
Table 2	Characteristics of Parking Facility
Table 3	Details of Repairs, and Slab Deterioration

The quantities of repairs required were summarized as:

Table 4	Repair Areas - Interior Suspended Slabs
Table 5	Repair Areas - Roof Slabs

Technical Assessment of Data

Given the subjective field data obtained in the survey, it was then necessary to convert this into quantitative data so that the extent of repairs and their costs could be determined.

Over the years, highway authorities including the Ministry of Transportation and Communications of Ontario, have had to deal with the problem of the investigation of many thousands of bridge decks which are deteriorating for the same reasons as the parking decks in apartment garages. A methodology has therefore been developed by these authorities and by Trow which delineates and classifies the extent of repairs needed based on visual surveys.

In converting the data in Tables 1, 2 and 3 into the quantities in Tables 4 and 5, this same methodology was used. Over the last three years Trow have applied this approach to parking structures, as well as to the bridge decks with which we have been involved during this period. In all, this system has been found applicable in the investigation of many parking structures and over 500 bridges, and Trow therefore believe that it is appropriate for the purposes of this type of survey.

The specific conversion criteria used, were as follows.

Cracks

Few - less than 1 m of cracks per 20 m² of parking deck.
Numerous - greater than 1 m per 4 m² of parking deck.

Delaminations

These were converted from the amount of spalling shown, as follows.

Few - small - 1% of total area of parking deck.
Few - large - 2% of total area of parking deck.
Numerous - small - 5% of total area of parking deck.
Numerous - large - 10% of total area of parking deck.

With regard to the costing of repairs needed, there are many ways in which a deteriorated parking structure can be repaired. In principle, it is best to remove any deteriorated concrete and replace it with new good quality concrete. It is generally necessary to replace or repair expansion joints, and depending on the repair system adopted, some kind of crack treatment will usually be necessary.

There are many ways of protecting a slab once it has been repaired:

1. Total replacement with new concrete.
2. Partial replacement with a high quality overlay.
3. Provision of an overlay on top of the existing slab made from a dense impermeable concrete of normal or special type.
4. Waterproofing of the repaired surface with any one of many types of proprietary waterproofing systems.

In order to determine the most suitable repairs for any specific garage, it is necessary to carry out a detailed engineering investigation and then to evaluate the extent and type of damage present at the time the investigation is carried out. It is also necessary to then evaluate this data in the light of the structural design of the structure involved. In this survey, this detailed approach was not possible. In order to arrive at an evaluation of the cost of repairing the present damage, it is therefore necessary to decide which alternative costing method should be used.

It is the experience of Trow that the installation of an overlay or a good quality waterproofing system after adequate concrete repairs have been completed, provides a long term cost effective solution.

In the experience of Trow, it is also quite common for building owners faced with the large repair costs involved, to accept the advice of suppliers or contractors who convince them that a lower cost solution, generally involving the application of a sealer, is an adequate alternative. While we do not agree with this latter approach, we felt that it would be instructive to include it in the costing.

In costing a good quality repair, it has been Trow's experience that generally there is not a large difference in cost between each of the high quality systems that can be considered. In developing the cost data in this report, it has been assumed that all the garages would be properly repaired and waterproofed with a high quality waterproofing system.

Financial Analysis of Data

Based on the summary given in Tables 4 and 5, Hellyar and Associates carried out a number of financial analyses of the repair work required. Their findings are attached to this report as Appendix "C".

In carrying out this analyses, standard financial calculation methods commonly used for determining life-cycle costs in the construction industry were used.

Insofar as unit rates and maintenance costs were concerned, these were based on Trow's past experience or wherever possible, on information supplied by the manufacturers of the various products.

Insofar as repair costs are concerned, the following unit rates were used.

(a)	Repair delaminated or spalled concrete	\$100.00 per m^2
(b)	Repair cracks in slabs	
	(1) where the slab is waterproofed	\$ 6.50 per m
	(2) where the slab is sealed	\$ 50.00 per m
(c)	Repair expansion joints	\$ 60.00 per m
(d)	Waterproofing membrane	\$ 27.00 per m^2
(e)	Sealer	\$ 7.00 per m^2
(f)	Remove landscaping	\$ 10.00 per m^2
(g)	Remove asphalt paving	\$ 10.00 per m^2
(h)	Remove remains of existing waterproofing and provide new waterproofing membrane	\$ 24.00 per m^2
(i)	Reinstate landscaping	\$ 10.00 per m^2
(j)	Reinstate paving	\$ 12.00 per m^2

With regard to the section on life cycle cost comparison, it should be noted that an arbitrary area was taken which is not related to the total area requiring treatment in this study sample.

It should also be noted in this, that where the life cycle costs for a sprayed sealer are included, no costs are included for the extensive repairs which would almost certainly be necessary.

In addition to the repair and maintenance costs shown, there would be Engineering costs. These would cover detailed investigation, assessment of repair options including any structural considerations, preparation of contract documents and obtaining and evaluating bids, contract supervision, and inspection and testing. Based on the experience of Trow, we would budget a total of $2.50 to $3.00 per m^2 of suspended slabs and roof slabs for this work.

For the 250,000 m^2 of slabs involved in this study, the Total Engineering costs would be between $625,000. and $750,000. or 6.3% and 7.5% of total repair costs.

FINDINGS

Based on the tabulated questionnaires, a number of the major findings are summarized in the following tables. For more detailed information, the original tables should be consulted.

Major Repairs Made to Parking Facilities

A total of 16 building owners/managers indicated that major repairs had been made to their parking facilities. This total is approximately 19% of all the buildings sampled. It appears also that major repairs are more prevalent in underground facilities and in structures of ± 9 - 10 years.

TABLE 6

"MAJOR" REPAIRS MADE TO PARKING FACILITY

BY AGE AND TYPE OF STRUCTURE

	UNDERGROUND		SURFACE FREE STANDING	
AGE (yrs.)	1 FLOOR	OVER 1 FLOOR	OVER 1 FLOOR	TOTAL
1-2	1	0	0	1
3-4	0	0	0	0
5-6	0	1	1	2
7-8	0	2	0	2
9-10	1	3	0	4
11-12	2	0	0	2
13-14	2	0	0	2
15-16	1	0	0	1
17-18	0	1	0	1
19-20	0	1	0	1
20 +	0	0	0	0
TOTAL	7	8	1	16

Cracks on Top Surface of Floor Slabs

Table 7 summarizes the data on parking facilities with "numerous easily visible cracks on top surfaces of floor slabs." Approximately 15% or 13 building owners/ managers indicated that many easily visible cracks exist on their surface slabs.

In addition, multi-level underground parking facilities 5 to 10 years old seem to exhibit this cracking characteristic most frequently.

TABLE 7

PARKING FACILITIES WITH

"NUMEROUS EASILY VISIBLE CRACKS ON TOP SURFACE"

BY AGE AND TYPE OF STRUCTURE

	UNDERGROUND	SURFACE FREE STANDING	
AGE (yrs.)	OVER 1 FLOOR	OVER 1 FLOOR	TOTAL
1-2	0	0	0
3-4	1	0	1
5-6	4	0	4
7-8	3	0	3
9-10	3	0	3
11-12	0	0	0
13-14	1	0	1
15-16	0	0	0
17-18	1	0	1
19-20	0	0	0
20 +	0	0	0
TOTAL	13	0	13

Spalling of Top Surfaces of Floor Slabs

In total, 17 parking facilities (approximately 20.0%) were reported to contain "numerous large spalls".

With respect to the age of structures, the spalling characteristic appears most frequently in the 5-10 year categories.

TABLE 8

PARKING FACILITIES WITH

"NUMEROUS LARGE SPALLS ON SURFACE OF TOP SIDE"

BY AGE AND TYPE OF STRUCTURE

	UNDERGROUND	SURFACE FREE STANDING	
AGE (yrs.)	OVER 1 FLOOR	OVER 1 FLOOR	TOTAL
1-2	0	0	0
3-4	1	1	2
5-6	4	2	6
7-8	2	0	2
9-10	5	1	6
11-12	0	0	0
13-14	1	0	1
15-16	0	0	0
17-18	0	0	0
19-20	0	0	0
20 +	0	0	0
TOTAL	13	4	17

Exposed Reinforcing Bars

Approximately 14% or 12 of the parking facilities surveyed reported that reinforcing bars were exposed.

TABLE 9

PARKING FACILITIES WITH EXPOSED RE-BARS

BY AGE AND TYPE OF STRUCTURE

	UNDERGROUND	SURFACE FREE STANDING	
AGE (yrs.)	OVER 1 FLOOR	OVER 1 FLOOR	TOTAL
1-2	0	0	0
3-4	1	0	1
5-6	3	0	3
7-8	2	0	2
9-10	4	0	4
11-12	0	0	0
13-14	1	0	1
15-16	0	0	0
17-18	1	0	1
19-20	0	0	0
20 +	0	0	0
TOTAL	12	0	12

Underside Floor Slab Cracks with Leaching Deposits

Of the total parking facilities surveyed, 23 parking structures (27.0%) contain "numerous underside cracks with leaching deposits". This characteristic appears most severe in multi-level underground parking lots. Furthermore, the incidence of this type of deterioration seems most prevalent in the 5-10 year age categories.

TABLE 10

PARKING FACILITIES WITH

"NUMEROUS UNDERSIDE CRACKS WITH LEACHING DEPOSITS"

BY AGE AND TYPE OF STRUCTURE

	UNDERGROUND		SURFACE FREE STANDING	
AGE (yrs.)	1 FLOOR	OVER 1 FLOOR	OVER 1 FLOOR	TOTAL
1-2	0	0	0	0
3-4	0	2	0	2
5-6	1	5	1	7
7-8	0	2	0	2
9-10	0	7	0	7
11-12	0	0	0	0
13-14	0	1	0	1
15-16	1	0	0	1
17-18	0	1	0	1
19-20	1	1	0	2
20+	0	0	0	0
TOTAL	3	19	1	23

Condition of Drains

In summary, the drains in the sampled parking facilities were functioning properly. That is, the grill and drain pipes were not clogged to hinder the movement of excess water. Approximately 71% of the facilities contained adequately maintained and functioning drains.

TABLE 11
CONDITION OF DRAINS IN PARKING FACILITIES

	Number	%
Functioning Properly	60	71
Clogged	24	29
TOTAL	84	100

Condition of Expansion Joints

The following two tables indicate the condition of the expansion joint waterseal and joint filler. The most prevalent condition reported indicates an expansion joint waterseal that is slightly leaking and a joint filler that is cracked.

TABLE 12
Condition of Expansion Joint Waterseal in Parking Facilities

	Number	%
Not Leaking	26	31
Slight Leaking	41	49
Severe Leaking	17	20
TOTAL	84	100

TABLE 13

Condition of Expansion Joint Filler in Parking Facilities

	Number	%
Uncracked	26	31
Cracked	41	49
Separated from Concrete	17	20
TOTAL	84	100

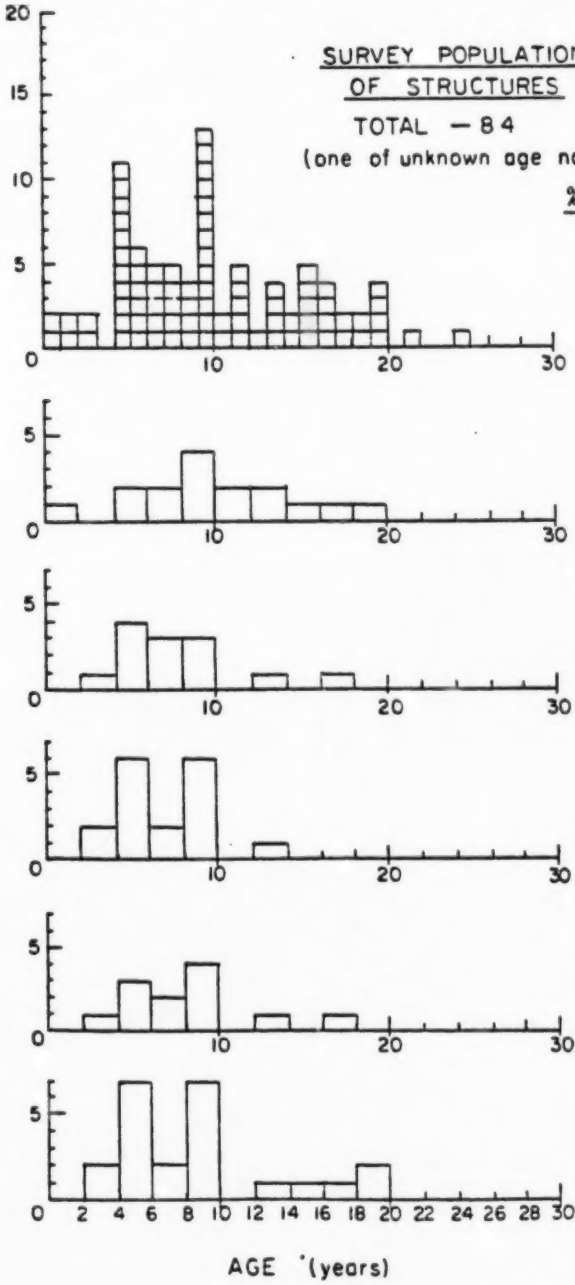
Repair Costs

The repair costs and life cycle costs are given in detail in Appendix "C".

Assessment of Data

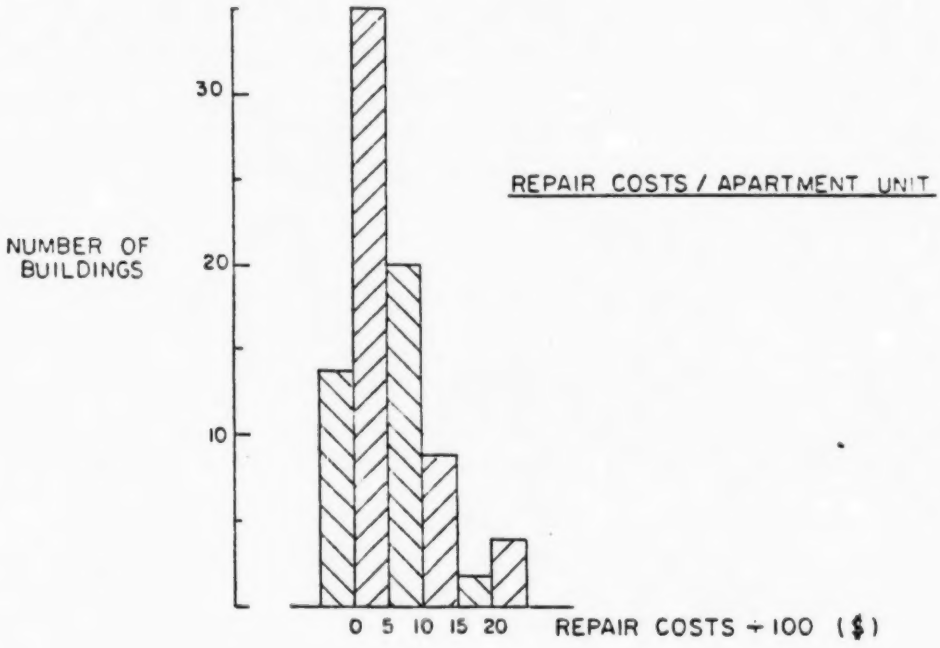
In order to illustrate the data, the following pictograms show the incidents of the defects shown in Tables 6 to 10, compared to the population of garages with age.

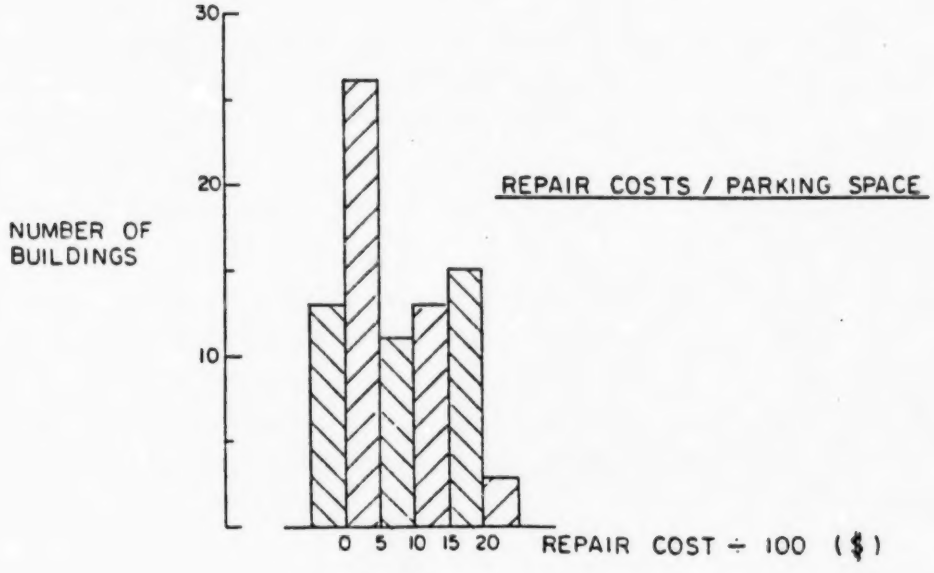
INCIDENCE OF DETERIORATION WITH AGE IN TERMS OF NUMBER OF STRUCTURES AFFECTED



VERTICAL AXIS IS NUMBER OF STRUCTURES.

Examining the data, it will be seen that there are approximately 16,300 units and 8,500 parking spaces involving structural concrete. If the data is examined further, it will be seen therefore, that the repair costs are very different if expressed per unit or per parking space. The following pictograms illustrate this point.





DISCUSSION

The results of the survey show that the 84 apartments surveyed require about $10,750,000. worth of repairs and engineering services to restore and protect the structural slabs of their parking structures. The experience of Trow and others, show that delaying such repairs escalates the cost disproportionately and also increases the risk of structural failure. This significant sum of money should therefore be expended soon to maximize its cost effectiveness.

A number of interesting facts emerged from the survey.

The percentage area of the structural slabs needing concrete repairs is estimated at 5%. Waterproofing of all such areas is recommended for future protection.

65% of the garages in this survey were reported as heated and 35% as unheated.

Reference to the tables and pictograms shows that the incidence of deterioration is greater in structures ten years old or less, than in older structures. The reasons for this are beyond the scope of this survey but one wonders if the 1971 building code introduced changes in standards that decreased durability, or if there is some other reason. It would be instructive to identify these reasons by further research.

The results are also surprising in that although the deterioration is extensive, it is not as severe or widespread as previous Trow experience would have predicted. Since Trow experience is primarily in the Toronto and surrounding area, there must be climatic or other reasons for the relatively better durability of Ottawa parking structures.

One possible reason is the higher design standards required in Ottawa because of earthquake requirements. Certainly, concrete materials and the quality of concrete supplied and workmanship are not, in Trow experience, superior in Ottawa compared to Toronto.

There is a wide range in cost per apartment unit or per parking space. An arbitrary division of ranges of costs have been shown in the pictograms on page 19. It is felt that repair costs of up to $500. per unit or per parking space are manageable within most budgets. Above this, the costs become increasingly onerous, and in the case of some condominium owners, impossible or close to impossible to manage - certainly when costs of $1,000. to $2,000. per unit are involved.

On an apartment unit basis, 35 of 85 or 42% require repairs greater than $500. and on a parking space basis, 42 of 84 or 50%. Similarly, the greater than $1,000. per unit category would encompass 15 of 84 or 18% of the apartment units or 31 of 84 or 37% of the parking spaces. The greater than $2,000. per unit category would encompass 4 of 84 or 5% of the apartment units or 3 of 84 or 4% of the parking spaces.

In terms of averages, the cost is about $600. per apartment unit for repairs, or $650. if engineering costs are included. For parking spaces, the comparable figures are $1,200. and $1,300. which is a significant percentage of the present capital cost of providing a parking space. While we do not have current costs for Ottawa, costs per space of the order of $4,000. to $5,500. per car would mean that even the average cost shown by our survey represent 20 to 25% of the original capital cost. For some of the structures surveyed, these costs go as high as 50 to 100% of original capital cost.

It should be noted that in analysing costs for parking spaces, we are only considering spaces which involve the provision of a structure. Surface parking is not considered, and it is a feature of many of the buildings in the survey sample that a high proportion of parking provided is in the form of surface parking. Consideration of the survey data shows this to be an economic approach in the Ottawa study area.

In considering the wide range of the costs of repairs in the same age ranges, the question arises as to what makes the difference and the answer to this question would also be worthy of further research.

In carrying out the life cycle cost study which shows that high quality repairs and protection systems are significantly cheaper than low cost, technically inferior ones, we have adopted a conservative approach currently in use in the construction industry. Other approaches in current use would show an even greater relative benefit from using this approach and would reinforce the wisdom of our recommendations on repair philosophy.

CONCLUSIONS

The residential buildings in the sample area exhibit the typical signs of deterioration common to all parking structures in areas where de-icing salts are used in winter. At the moment, the 84 structures in the sample survey require approximately $10,000,000. worth of repairs and $750,000. worth of engineering services to restore them to acceptable condition and to protect them from further significant deterioration assuming normal maintenance is continued.

For the Ottawa area, surface parking appears to be an economic alternative.

The financial analysis further confirms that the recommended system of repairs and waterproofing carried out to high standards is significantly cheaper in the long run than the use of less desireable but initially cheaper repair methods.

RECOMMENDATIONS

It is recommended that a larger sample, covering a number of other geographic areas, be surveyed to determine to what extent the initial survey area was typical of the rest of Canada. This survey should also include sufficient technical input to determine why the structures greater than 10 years old appear to be more durable and why, within the same age ranges, there is a wide difference in the durability performances of similar structures.

It is further recommended that existing programmes such as RRAP be examined to see if some relief can be afforded to the owners of residential property - particularly condominium owners.

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Please Note

pages 27 to 125 of the original report have not been included in this abridged edition. The complete edition is available for consultation only at the Canadian Housing Information Centre.

APPENDIX "A"

Introductory Letter

Real Estate Consultants

- Market Studies
- Feasibility Analysis
- Appraisals
- Development Analysis
- Assessment Reviews
- Investment Studies

Realty Research Group Ltd.

Ste 610, 75 Donway West, Don Mills, Ontario M3C 2E9 Telephone (416) 449-5874

March , 1981

Dear Sir:

Our company along with Trow Ltd., Consulting Engineers, have been hired by the CMHC Technical Research Department to make the initial contact with Ottawa area apartment building owners regarding possible deterioration of concrete parking structures. This is an increasingly serious problem in Ontario, resulting from damage caused in the most part by the salt used on the roads.

Almost all parking structures in Ontario built to existing design and construction standards are deteriorating. The costs of repair can, after only a few years of service, equal or exceed the initial construction cost. To date no concerted efforts have been made to solve these problems.

It will be extremely beneficial for apartment owners to participate in this research program, since the cooperation of as many owners as possible will help to identify the problem areas. We feel that the successful completion of this research program will be the first step in developing a solution to the problem.

A researcher will be phoning in the next few days to set up an interview time with the appropriate individual(s) within your firm and arrange a suitable date for the inspection of your parking facilities at the apartments listed on the attached sheet. By agreement with CMHC your responses will be kept strictly confidential from them. The findings will be made available to you upon request after the survey has been completed.

To enable you to prepare for our questions, we are enclosing a copy of the survey that we shall be completing at the time of our visit.

Thank you for your cooperation in this matter.

Yours very truly,
REALTY RESEARCH GROUP LTD.

R.J. Zavistake, B.Comm., M.Sc.,
President
RJZ/lw

APPENDIX "B"

Interview Questionnaire

MAP AREA: _____

PROJECT REF. NO.: _____

CMHC - OTTAWA RESIDENTIAL PARKING FACILITY SURVEY

A. GENERAL INFORMATION

A-1. Name of Development: _____

A-2. Address of Development: _____

A-3. Name of Owner: _____ Contact Person: _____

A-4. Address of Owner: _____ Tel. No.: _____

A-5. Date completed and age of structure: Proj. Tel.No.: _____

	Date Completed	Age	Estimated Initial Cost
(a) Building	.....	.....	
(b) Parking Facility	.....	.....	$ .....

A-6. Number of Units: (a) Rental Apartments: _____ units
(b) Condominiums: _____ units

B. PARKING FACILITY

B-1. Size of Parking Facility

	No. Spaces	Dimensions		Area	
		Metres	Feet	M^2	Sq.Ft.
(a) Surface Free Standing Structure (from ground to top floor)					
(i) Ground Floor	.....	....x....	....x....	.....	.....
(ii) 2nd Floor	.....	....x....	....x....	.....	.....
(iii) 3rd Floor	.....	....x....	....x....	.....	.....
(iv) 4th Floor	.....	....x....	....x....	.....	.....

(b) Under Ground
(from bottom to ground floor)

(i) Bottom Floor	.....	....x....	....x....	.....	.....
(ii) 2nd Floor	.....	....x....	....x....	.....	.....
(iii) 3rd Floor	.....	....x....	....x....	.....	.....
(iv) 4th Floor	.....	....x....	....x....	.....	.....
(c) Other:	.....	....x....	....x....	.....	.....
(d) Other:	.....	....x....	....x....	.....	.....
TOTAL					

B-2. Level of Utilization (or Occupancy Rate) of Parking Facility and Rental Fee:

	Winter Period	Rest of Year	Rental Fee
(a) Surface Free Standing:	____ %	____ %	$ ____ / month
(b) Underground:	____ %	____ %	$ ____ / month
(c) Other: ____ :	____ %	____ %	$ ____ / month
(d) Other: ____ :	____ %	____ %	$ ____ / month

B-3. Are plans of the parking facility available?

☐ No

☐ Yes Where ? _____

B-4. Type of Construction:

	(a) Surface Free Standing Structure	(b) Underground	(c) Other: ____
Reinforced Concrete			
Steel Framed			
Pre Stressed Concrete			
Pre Cast Concrete Floor Slabs			
Combination of Above (describe)			

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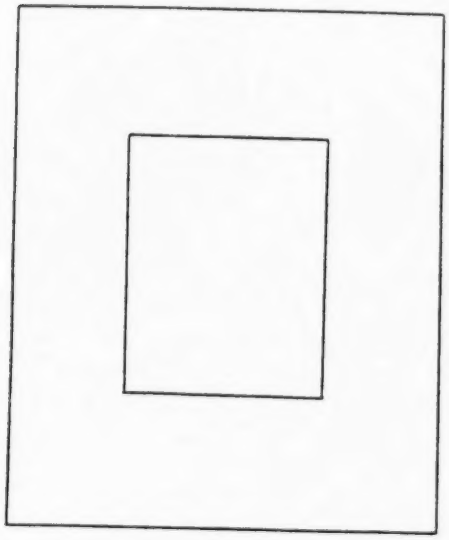
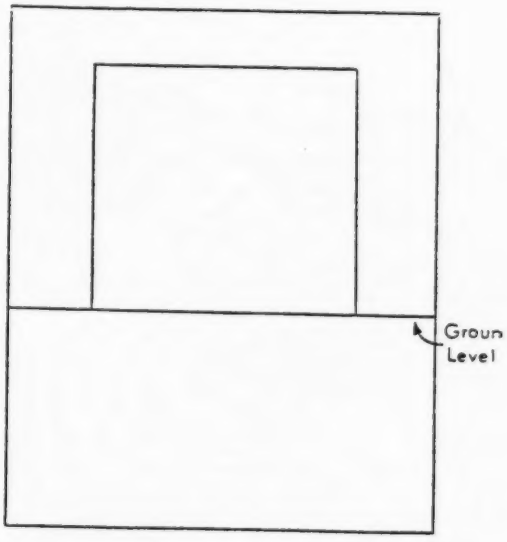
C. TYPICAL LAYOUT OF THE GARAGE (Surveyor Draw Plan)

Plan



Cross-Section



(a) Shade in the above ground parking. Outline exterior garage walls and show location of entrance/exit ramps.

(b) Outline parking floors, interior walls and ramps.

D. SUMMARY OF REPAIRS AND ALTERATIONS

D-1. Do you have a regular maintenance program in effect?

☐ No — If No, why not: _____

☐ Yes — If Yes, please describe your program and cost: _____

Estimated Annual Spending:

$ _____ / yr.

D-2. Repair work previously carried out:

Type/Cause	Extent of Repairs (% of Total Area)	Date of Repair	Cost
(a) Past Repairs and Alterations:			$
(b) Future Repairs and Alterations:			$

E. EVIDENCE OF PHYSICAL DETERIORATION

E-1. Top Surface of Parking Slabs

(a) Cracks in the Surface

(i) Amount of Cracks

- ☐ None,
- ☐ Few (< 1 m long per 20 m^2), (3'/215 sf)
- ☐ Numerous (>1 m long per 4 m^2) (3'/43 sf)

(ii) Width of Cracks

- ☐ Barely Visible,
- ☐ Easily Visible,
- ☐ 0.5 mm or greater

(b) Concrete Spalls (if concrete surface is covered, view from underside)

(i) Amount of Spall

- ☐ None,
- ☐ Few (<1% of Total Area)
- ☐ Numerous (> 2% of Total Area)

(ii) Average Size of Spall

- ☐ Small (diameter < 200 mm)(8")
- ☐ Large (diameter >200 mm)(8")

(c) Exposed Reinforcing Bars (if concrete surface is covered, view from underside)

(i) Amount of Exposed Bars

- ☐ None
- ☐ Few
- ☐ Numerous

(ii) Condition of Bars

- ☐ Unrusted
- ☐ Slightly Rusted
- ☐ Severely Rusted

E-2. Underside of Parking Slabs

(a) Cracks in the Concrete with Associated Leach Deposits

- ☐ None
- ☐ Few (<1 m long per 20 m^2) (3'/215 sf.)
- ☐ Numerous (>1 m long per 4 m^2) (3'/43 sf.)

(b) Scaling of Concrete

- ☐ None
- ☐ Slight (< 1% of Total Area)
- ☐ Severe (> 2% of Total Area)

F. CHARACTERISTICS OF PARKING FACILITY

	Waterproof Membrane on floor slabs		Heating		Floor to Underside Floor Slab Height		Condition of Drains			Condition of Expansion Joints	
	Yes	No	Heated	Unheated	(mm.)	(in.)	No.	Size & Type	Condition[1] (FF, C)	Watertight[2] (NL, SL, SV)	Joint Filler[3] (UC, CR, SC)
(a) Surface Free Standing Structure (go from ground to top floor)											
(i) Ground Floor											
(ii) 2nd Floor											
(iii) 3rd Floor											
(iv) 4th Floor											
(b) Under Ground (go from bottom to top floor)											
(i) Bottom Floor											
(ii) 2nd Floor											
(iii) 3rd Floor											
(iv) 4th Floor											
(c) Other:											
(d) Other:											
TOTAL											

(1) FF = Functioning Properly; C = Clogged

(2) NL = No leakage; SL = Slight; SV = Severe

(3) UC = Uncaulked; CR = Cracked; SC = Separated from concrete.

NATURE, EXTENT, AND IMPACT OF RESIDENTIAL PARKING STRUCTURE DETERIORATION

APPENDIX " C "

CALCULATION OF ECONOMIC IMPACT OF STATISTICAL DATA RECEIVED

JUL 2 0

Prepared by: G. J. Fleming
Helyar & Associates

INTRODUCTION

This section of the report attempts to determine the probable cost of repairing the deteriorated areas of the residential parking structures surveyed, and to indicate the possible scale nationwide of the problem of deteriorating residential parking structures.

An attempt has also been made to show the proper comparison, over the life of the structure, between the cost of a structure which has been protected with a waterproofing membrane and a structure which has not been properly waterproofed.

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1. Estimated Cost of Repair Work Required

2. Life Cycle Cost Comparison - Waterproofed Structure vs Unprotected Structure

3. Conclusions

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1. ESTIMATED COST OF REPAIR WORK REQUIRED

1. ESTIMATED COST OF REPAIR WORK REQUIRED

The following is a summary of the repair work which is presently required in the garages surveyed:-

Interior Suspended Slabs

Repair delaminated or spalled concrete	9 349 m²
Repair cracks in slabs	31 384 m
Repair expansion joints	6 387 m

Roof Slabs

Re-waterproof slab (landscaped above)	50 287 m²
Re-waterproof slab (asphalt above)	38 156 m²
Repair cracks in slabs	8 316 m

1. ESTIMATED COST OF REPAIR WORK REQUIRED CONTINUED

There are two methods of repairing the interior suspended slabs:-

Method 1

This involves repairing delaminated or spalled concrete, repairing expansion joints, and protecting the complete slab with a waterproofing membrane.

Method 2

This involves epoxy injection of cracks, repairing expansion joints, and protecting the slab with a sealer. (It should be noted that a sealer cannot bridge cracks and tends to wear out very quickly. The life cycle cost calculation which follows later in this report considers the cost of a sealer over the life of a structure, and makes allowance for frequent replacement of the sealer and parking disruptions.)

There are also two methods of repairing the roof slabs, but only the first method will provide for a lasting solution.

Method 1

This involves removing landscaping or asphalt paving and the remains of any existing waterproofing. The slab is then protected with a new waterproofing membrane, and the landscaping and asphalt is re-instated.

Method 2

This involves epoxy injection of cracks from the underside of the slab, and requires continuing maintenance of the underside of the slab and the surface of asphalt paving above.

1. ESTIMATED COST OF REPAIR WORK REQUIRED CONTINUED

SUMMARY OF ESTIMATED REPAIR COSTS

Work Required	Method 1	Method 2
INTERIOR SUSPENDED SLABS		
a) Repair delaminated or spalled concrete	935,000	n/a
b) Repair cracks in slabs	204,000	1,570,000
c) Repair expansion joints	383,000	383,000
d) Waterproofing membrane	4,246,000	n/a
e) Sealer	n/a	1,100,000
ROOF SLABS		
a) Remove landscaping	503,000	n/a
b) Remove asphalt paving	382,000	n/a
c) Remove remains of existing waterproofing; new waterproofing membrane	2,123,000	n/a
d) Repair cracks in slabs	54,000	416,000
e) Re-instate landscaping (excluding tree renewal)	503,000	n/a
f) Re-instate paving	458,000	n/a
	$ 9,791,000	$ 3,469,000

1. ESTIMATED COST OF REPAIR WORK REQUIRED CONTINUED

It can be seen that the second methods described for treating the floor and roof slabs are considerably less expensive than the first methods; however no allowance has been made in the above calculations for recurring maintenance costs. These would be substantial throughout the life of a structure if the second repair method was adopted.

There are approximately 15,500 residential units contained in the buildings surveyed. The cost per unit of the repairs currently required is $632.00 for the work described as Method 1, and $224.00 for Method 2.

Bearing in mind that major repairs have already been carried out in 19% of the structures surveyed, the actual cost per unit of repairs resulting from deteriorating parking structures will be considerably greater than calculated above.

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2. LIFE CYCLE COST COMPARISON - WATERPROOFED STRUCTURE vs UNPROTECTED STRUCTURE

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2. LIFE CYCLE COST COMPARISON - WATERPROOFED STRUCTURE vs UNPROTECTED STRUCTURE

PREAMBLE

The purpose of this exercise is to show the comparison of total costs (i.e. initial and maintenance costs) between a new parking garage with no treatment to the structural floor surface and the same garage treated with a range of proprietary floor finishes.

Allowance has been made in the calculations for the loss of revenue which would be sustained during maintenance operations, assuming a parking rate similar to the buildings surveyed.

The assumed frequency of maintenance work required for each of the products considered was based on the author's interpretation of information provided by the product manufacturers.

The material prices shown are based on budget prices provided by the product manufacturers. Actual tender prices may vary depending on the nature of work tendered.

2. LIFE CYCLE COST COMPARISON - WATERPROOFED STRUCTURE vs UNPROTECTED STRUCTURE

SUMMARY OF NET PRESENT VALUES

		$	Parking Disruptions
A.	Untreated	1,521,769	3
B.	Sprayed Sealer	1,017,840*	39
C.	TAPECRETE Treatment	572,278	3
D.	HYDROTECH Treatment	592,108	4
E.	PRC Treatment	612,108	4
F.	MAMECO Treatment	581,979	3
G.	BEMAC Treatment	502,278	3
H.	KELMAR Treatment	522,278	3
I.	XYPEX Treatment ≠	492,108 *	4

(* - cost excludes structural repairs)

Note The following assumptions were made in the calculations:-

i) area of garage suspended floors - 20 000 m²

ii) interest rate - 15% p.a.

iii) functional life of garage - 40 years

iv) parking rate per car - $25 per month

v) garage capacity - 615 cars

≠ The inclusion of this material does not imply that we believe it to be effective - we have, in fact, no experience of its performance.

2. LIFE CYCLE COST COMPARISON - WATERPROOFED STRUCTURE vs UNPROTECTED STRUCTURE CONTINUED

A. Untreated

Initial Cost	Nil
Maintenance Costs	
i) Year 10 - 20 000 m² x $300.00 x 0.2471847	1 483 108
ii) Year 20 - 20 000 m² x $ 11.00 x 0.0611003	13 442
iii) Year 30 - 20 000 m² x $ 11.00 x 0.0151031	3 323
Loss of Revenue	
i) Year 10 (25 weeks) = $87,500.00 x 0.2471847	21 629
ii) Year 20 (1 week) = $ 3,500.00 x 0.0611003	214
iii) Year 30 (1 week) = $ 3,500.00 x 0.0151031	53
Total Net Present Value of Untreated Slab	$ 1 521 769

Notes

a) Allowance has been made for major structural repairs at the end of Year 10, plus the addition of a water-proofing membrane.

b) Maintenance costs at Year 20 and Year 30 are for maintaining the traffic topping to the membrane which was installed at the end of Year 10.

2. LIFE CYCLE COST COMPARISON - WATERPROOFED STRUCTURE vs UNPROTECTED STRUCTURE CONTINUED

B. Sprayed Sealer

Initial Cost (20 000 m² x $3.25)	65 000
Maintenance Costs	
Year 1 to Year 39 - 20 000 m² x $7.00 x 6.64	929 600
Loss of Revenue (assuming 1 week p.a.)	
Year 1 to Year 39 - $3 500.00 x 6.64	23 240
Total Net Present Value of Sprayed Sealer	$ 1 017 840

Notes

a) Allowance has been made for renewing the sprayed sealer treatment at the end of each year. (The cost of renewing the sealer is much greater than the original cost because of the additional preparatory work required on old surfaces.)

b) No allowance has been made for structural repairs which could be required if the sealer wears out, or if any cracks appear in the structure, since the sealer treatment cannot bridge small cracks. This situation would then be similar to the calculation for the untreated structure.(Item A of this exercise.)

2. LIFE CYCLE COST COMPARISON - WATERPROOFED STRUCTURE vs UNPROTECTED STRUCTURE CONTINUED

C. TAPECRETE Treatment

Initial Cost (20 000 m² x $25.00)	500 000
Maintenance Costs	
i) Year 10 - 20 000 m² x $11.00 x 0.2471847	54 381
ii) Year 20 - 20 000 m² x $11.00 x 0.0611003	13 442
iii) Year 30 - 20 000 m² x $11.00 x 0.0151031	3 323
Loss of Revenue	
i) Year 10 (1 week) - $3 500.00 x 0.2471847	865
ii) Year 20 (1 week) - $3 500.00 x 0.0611003	214
iii) Year 30 (1 week) - $3 500.00 x 0.0151031	53
Total Net Present Value of TAPECRETE Treatment	$ 572 278

Note

Allowance has been made for normal maintenance of the traffic topping.

2. LIFE CYCLE COST COMPARISON - WATERPROOFED STRUCTURE vs UNPROTECTED STRUCTURE CONTINUED

D. HYDROTECH Treatment

Initial Cost (20 000 m² x $24.00)	480 000
Maintenance Costs	
i) Year 8 - 20 000 m² x $11.50 x 0.3269018	75 187
ii) Year 16 - 20 000 m² x $11.50 x 0.1068648	24 579
iii) Year 24 - 20 000 m² x $11.50 x 0.0349343	8 035
iv) Year 32 - 20 000 m² x $11.50 x 0.0114201	2 627
Loss of Revenue	
i) Year 8 (1 week) - $ 3 500.00 x 0.3269018	1 144
ii) Year 16 (1 week) - $ 3 500.00 x 0.1068648	374
iii) Year 24 (1 week) - $ 3 500.00 x 0.0349343	122
iv) Year 32 (1 week) - $ 3 500.00 x 0.0114201	40
Total Net Present Value of HYDROTECH Treatment	$ 592 108

Note

Allowance has been made for normal maintenance of the traffic topping.

2. LIFE CYCLE COST COMPARISON - WATERPROOFED STRUCTURE vs UNPROTECTED STRUCTURE CONTINUED

E. PRC Treatment

Initial Cost (20 000 m² x $25.00)	500 000
Maintenance Costs	
i) Year 8 - 20 000 m² x $11.50 x 0.3269018	75 187
ii) Year 16 - 20 000 m² x $11.50 x 0.1068648	24 579
iii) Year 24 - 20 000 m² x $11.50 x 0.0349343	8 035
iv) Year 32 - 20 000 m² x $11.50 x 0.0114201	2 627
Loss of Revenue	
i) Year 8 (1 week) - $ 3 500.00 x 0.3269018	1 144
ii) Year 16 (1 week) - $ 3 500.00 x 0.1068648	374
iii) Year 24 (1 week) - $ 3 500.00 x 0.0349343	122
iv) Year 32 (1 week) - $ 3 500.00 x 0.0114201	40
Total Net Present Value of PRC Treatment	$ 612 108

Note

Allowance has been made for normal maintenance of the traffic topping.

2. LIFE CYCLE COST COMPARISON - WATERPROOFED STRUCTURE vs UNPROTECTED STRUCTURE CONTINUED

F. MAMECO Treatment

Initial Cost (20 000 m² x $25.00)	500 000
Maintenance Costs	
i) Year 10 - 20 000 m² x $12.50 x 0.2471847	61 796
ii) Year 20 - 20 000 m² x $12.50 x 0.0611003	15 275
iii) Year 30 - 20 000 m² x $12.50 x 0.0151031	3 776
Loss of Revenue	
i) Year 10 (1 week) - $ 3 500.00 x 0.2471847	865
ii) Year 20 (1 week) - $ 3 500.00 x 0.0611003	214
iii) Year 30 (1 week) - $ 3 500.00 x 0.0151031	53
Total Net Present Value of MAMECO Treatment	$ 581 979

Note

Allowance has been made for normal maintenance of the wearing surface.

2. LIFE CYCLE COST COMPARISON - WATERPROOFED STRUCTURE vs UNPROTECTED STRUCTURE CONTINUED

G. BEMAC Treatment

Initial Cost (20 000 m² x $21.50)	430 000
Maintenance Costs	
i) Year 10 - 20 000 m² x $11.00 x 0.2471847	54 381
ii) Year 20 - 20 000 m² x $11.00 x 0.0611003	13 442
iii) Year 30 - 20 000 m² x $11.00 x 0.0151031	3 323
Loss of Revenue	
i) Year 10 (1 week) - $ 3 500.00 x 0.2471847	865
ii) Year 20 (1 week) - $ 3 500.00 x 0.0611003	214
iii) Year 30 (1 week) - $ 3 500.00 x 0.0151031	53
Total Net Present Value of BEMAC Treatment	$ 502 278

Note

Allowance has been made for normal maintenance of the wearing surface.

2. LIFE CYCLE COST COMPARISON - WATERPROOFED STRUCTURE vs UNPROTECTED STRUCTURE CONTINUED

H. KELMAR Treatment

Initial Cost (20 000 m² x $22.50)	450 000
Maintenance Costs	
i) Year 10 - 20 000 m² x $11.50 x 0.2471847	54 381
ii) Year 20 - 20 000 m² x $11.50 x 0.0611003	13 442
iii) Year 30 - 20 000 m² x $11.00 x 0.0151031	3 323
Loss of Revenue	
i) Year 10 (1 week) - $ 3 500.00 x 0.2471847	865
ii) Year 20 (1 week) - $ 3 500.00 x 0.0611003	214
iii) Year 30 (1 week) - $ 3 500.00 x 0.0151031	53
Total Net Present Value of KELMAR Treatment	$ 522 278

Note

Allowance has been made for normal maintenance of the wearing surface.

2. LIFE CYCLE COST COMPARISON - WATERPROOFED STRUCTURE vs UNPROTECTED STRUCTURE CONTINUED

I XYPEX Treatment

Initial Cost (20 000 m² x $19.00)	380 000
Maintenance Costs	
i) Year 8 - 20 000 m² x $11.50 x 0.3269018	75 187
ii) Year 16 - 20 000 m² x $11.50 x 0.1068648	24 579
iii) Year 24 - 20 000 m² x $11.50 x 0.0349343	8 035
iv) Year 32 - 20 000 m² x $11.50 x 0.0114201	2 627
Loss of Revenue	
i) Year 8 (1 week) - $ 3 500.00 x 0.3269018	1 144
ii) Year 16 (1 week) - $ 3 500.00 x 0.1068648	374
iii) Year 24 (1 week) - $ 3 500.00 x 0.0349343	122
iv) Year 32 (1 week) - $ 3 500.00 x 0.0114201	40
Total Net Present Value of XYPEX Treatment	$ 492 108

Notes

a) Allowance has been made for normal maintenance of the traffic topping.

b) No allowance has been made for structural repairs which could be required if any cracks appear in the structure since this treatment is crystalline and cannot bridge small cracks.

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3. CONCLUSIONS

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3. CONCLUSIONS

The results of this study show that there is a considerable amount of work required to correct the effects of deterioration on residential parking structures in Ottawa.

The cost per residential unit of correcting the deterioration would probably be much greater if a similar study was carried out in Toronto. This assumption is based on the fact that the cost of land is generally higher in Toronto, and site densities are greater. This means that there will be a higher ratio of suspended parking garage floor slabs per residential unit in Toronto than in Ottawa.

It may also be a factor worth some consideration that structures in Ottawa are designed to withstand greater earthquake forces than in most other parts of the country. They may therefore perhaps be designed and constructed with greater integrity in Ottawa than in other cities, which would be another indication that the problem of deterioration may not be so serious in Ottawa as it is elsewhere in the country.

The life-cycle cost exercise appears to confirm that it is more economic in the long term to construct a parking garage with a proper waterproofing membrane on the suspended slabs, rather than to carry out continuing repairs on an untreated structure. It should be noted, however, that no allowance was made in the exercise for the effect of current tax regulations on the decision by a building owner whether to incur additional initial capital costs or to incur ongoing maintenance costs.

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APPENDIX "E"
Description of Common Defects

Cracking

Concrete cracking is caused by stress. This stress is either construction or service related. Cracking commonly attributed to construction is caused by improper concrete placement, improper consolidation, improper curing of the concrete, premature removal of form supports, or by plastic shrinkage of the concrete. Service related cracking is usually due to temperature changes, load, settlement, or internal stress. Corrosion of rebars and aggregate chemical reaction are common causes of internal stress.

Not all cracking is detrimental to the concrete member. In many cases, cracks are anticipated and reinforcement is provided to transfer stress across the crack. Property positioned reinforcement arrests crack development by keeping cracks short and tightly closed. Cracking can be detrimental when it occurs to an extent and frequency not expected. If this happens, steps are necessary to minimize the effect cracking has on long term structure durability or durabilty of a specific member.

Spalling

Concrete spalling, by technical definition, is the end result of corrosion-induced stress. It is preceeded by an internal horizontal fracture (delamination) which migrates from the steel to the surface over a period of time. When such fractures reach the surface, they allow the concrete to break away leaving an open spall

or pot-hole. The corrosion process is accelerated to many times its normal rate by the presence of chloride or road salt. Salt is used as a deicing agent to minimize the hazards of winter driving.

Scaling

Concrete scaling is a deterioration mechanism which attacks the mortar fraction (sand and cement) of the concrete mix. It is characterized initially as a minor flaking and disintegration of the concrete surface. With passing time it progresses deeper into the concrete, eventually exposing aggregate which breaks away. This further contributes to the process by exposing more paste to the elements. In extreme cases, apparently sound concrete can be reduced to a gravel-like condition in a short period of time.

Concrete scaling is caused by freeze-thaw action. All concrete has a certain normal amount of water stored in the mortar fraction. When concrete is frozen in a surface-dry state, there is little damage. If concrete is frozen in a saturated state, excess water freezing in the concrete causes high stress and weakens the mortar. Cyclic exposure to freeze-thaw action is very destructive to concrete in a saturated state.

Pop-outs in the concrete surface also result from freeze-thaw action, but originate within the coarse aggregate. Certain aggregares have a porous structure which permits penetration by water. Upon freezing, the water expands, fracturing the aggregate and resulting in a pit typically one to two inches in diameter in the concrete surface.

Leaching

Leaching is caused by frequent water migration through the floor slab or cracks. As water migrates through, it takes along part of the cementing constituents, depositing them as a white film, stain, or in extreme cases, stalactite on the ceiling below. This process will weaken the concrete over a period of years and is accelerated by porous or perpetually moist concrete. Leaching frequently occurs from cracks beneath gutterlines.

Joint Deterioration

The two most common provisions made for providing crack control or relief of restraint in concrete slabs are control joints and expansion joints. Such joints have long been a source of maintenance problems. Joints on supported floor slabs must be sealed against water leakage and intrusion of incompressibles. Both situations are damaging to the joint system.

Construction joints deteriorates for several reasons usually associated with failure of the sealant or failure of the adjacent concrete. Joint sealants may not have the required degree of flexibility, bond, strength, or durability for a particular application. If concrete adjacent to the joint is not sufficiently durable, then local scaling will cause joint sealant failure.

Expansion joints are also susceptible to premature deterioration. The most common cuases of early deterioration are: improper joint design or sealant material specifications, incorrect installation of the expansion device, and in-service damage from traffic or snow plows.